

Matrix Factorization for Movie Recommendation Systems

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b0.5 **Maybe because of:**

- ▶ Genre (Action, Romance, Comedy)

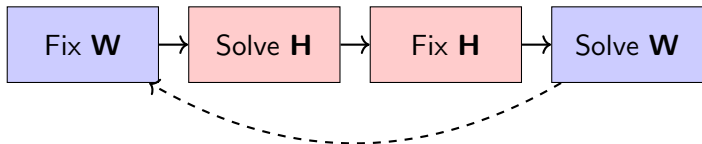
$$\hat{a}_{11} = \mathbf{w}_1^T \mathbf{h}_1 \quad (1)$$

$$= w_{11} \cdot 0.95 + w_{12} \cdot 0.10 + w_{13} \cdot 0.85 \quad (2)$$

Goal: Find w_{11} , w_{12} , w_{13} such that $\hat{a}_{11} \approx 5$ (Alice's actual rating)

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Initialize: $\mathbf{W}^{(0)}$ and $\mathbf{H}^{(0)}$ randomly



$$\text{minimize}_{\mathbf{w}_i} \sum_{j:(i,j) \in \Omega} (a_{ij} - \mathbf{w}_i^T \mathbf{h}_j)^2$$

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Matrix Form for User i : Let $\Omega_i = \{j : (i, j) \in \Omega\}$ (movies rated by user i)

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$$\mathbf{y}_i = [a_{i,j_1}, a_{i,j_2}, \dots, a_{i,j_{|\Omega_i|}}]^T \quad (3)$$

$$\mathbf{X}_i = [\mathbf{h}_{j_1}, \mathbf{h}_{j_2}, \dots, \mathbf{h}_{j_{|\Omega_i|}}]^T \quad (4)$$

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Least Squares Solution:

$$\boxed{\mathbf{w}_i^* = (\mathbf{X}_i^T \mathbf{X}_i)^{-1} \mathbf{X}_i^T \mathbf{y}_i}$$

$$\mathbf{y}_1 = \begin{bmatrix} 5 \\ 4 \\ 2 \\ 3 \\ 2 \end{bmatrix} \quad (5)$$

$$\mathbf{X}_1 = \begin{bmatrix} 0.95 & 0.10 & 0.85 \\ 1.00 & 0.20 & 0.90 \\ 0.05 & 0.80 & 0.30 \\ 0.05 & 0.95 & 0.70 \\ 0.05 & 0.15 & 0.95 \end{bmatrix} \quad (6)$$

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Solution: $\mathbf{w}_1^* = (\mathbf{X}_1^T \mathbf{X}_1)^{-1} \mathbf{X}_1^T \mathbf{y}_1$

This gives us Alice's feature preferences!

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Matrix Form for Movie j : Let $\Omega_j = \{i : (i, j) \in \Omega\}$ (users who rated movie j)

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$$\mathbf{y}_j = [a_{i_1,j}, a_{i_2,j}, \dots, a_{i_{|\Omega_j|},j}]^T \quad (7)$$

$$\mathbf{X}_j = [\mathbf{w}_{i_1}, \mathbf{w}_{i_2}, \dots, \mathbf{w}_{i_{|\Omega_j|}}]^T \quad (8)$$

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Objective Function:

$$L(\mathbf{W}, \mathbf{H}) = \sum_{(i,j) \in \Omega} (a_{ij} - \mathbf{w}_i^T \mathbf{h}_j)^2$$

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Gradients:

$$\frac{\partial L}{\partial \mathbf{w}_i} = -2 \sum_{j: (i,j) \in \Omega} (a_{ij} - \mathbf{w}_i^T \mathbf{h}_j) \mathbf{h}_j \quad (9)$$

$$\frac{\partial L}{\partial \mathbf{h}_j} = -2 \sum_{i: (i,j) \in \Omega} (a_{ij} - \mathbf{w}_i^T \mathbf{h}_j) \mathbf{w}_i \quad (10)$$

Your Process:

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1. Make a guess about their rating

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2. See their actual rating

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SGD does exactly this!

- ▶ One rating at a time
- ▶ Small adjustments
- ▶ Gradually improves

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$$\mathbf{w}_i \leftarrow \mathbf{w}_i + \alpha \cdot e_{ij} \cdot \mathbf{h}_j \quad (11)$$

$$\mathbf{h}_j \leftarrow \mathbf{h}_j + \alpha \cdot e_{ij} \cdot \mathbf{w}_i \quad (12)$$

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- If $e_{ij} > 0$: Predicted rating too low \rightarrow Increase similarity

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Intuition:

- ▶ If $e_{ij} > 0$: Predicted rating too low \rightarrow Increase similarity
- ▶ If $e_{ij} < 0$: Predicted rating too high \rightarrow Decrease similarity
- ▶ Learning rate α controls step size

$$\text{Current: } \mathbf{w}_1 = [0.4, 0.2, 0.3], \quad \mathbf{h}_1 = [0.95, 0.10, 0.85] \quad (13)$$

$$\text{Prediction: } \hat{a}_{11} = 0.4 \times 0.95 + 0.2 \times 0.10 + 0.3 \times 0.85 = 0.655 \quad (14)$$

$$\text{Error: } e_{11} = 5 - 0.655 = 4.345 \quad (15)$$

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Updates with $\alpha = 0.01$:

$$\mathbf{w}_1 \leftarrow [0.4, 0.2, 0.3] + 0.01 \times 4.345 \times [0.95, 0.10, 0.85] \quad (16)$$

$$= [0.4413, 0.2043, 0.3369] \quad (17)$$

$$\mathbf{h}_1 \leftarrow [0.95, 0.10, 0.85] + 0.01 \times 4.345 \times [0.4, 0.2, 0.3] \quad (18)$$

$$= [0.9674, 0.1087, 0.8631] \quad (19)$$

!

Answers:

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$$\mathbf{X}_1 = \begin{bmatrix} 1.0 & 0.3 \\ 0.2 & 0.8 \end{bmatrix} \text{ (columns 1,3 of } \mathbf{H}^{(0)T} \text{)}$$

Solve: $\mathbf{w}_1^{(1)} = (\mathbf{X}_1^T \mathbf{X}_1)^{-1} \mathbf{X}_1^T \mathbf{y}_1$

Continue for all users and movies...

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matrix factorization can only work with explicit ratings

Answers:

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Questions?

Thank you for your attention!

Next: Deep learning approaches to recommendation systems